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♦ Banque de France, International Macroeconomics Division, Matthieu.Bussiere@banque-france.fr.

Abstract

The 2008 financial crisis has rekindled interest in the issue of early warning signals (EWS) of financial distress. It has also triggered renewed interest in the literature on currency crises, with many countries, especially among emerging market economies, experiencing severe exchange market pressure. While several policy institutions are in the process of developing new early warning systems, there is a lot of skepticism on the ability to predict currency crises or, more generally, any type of financial crises. This skepticism stems from the alleged poor out-of-sample performance of leading models, but also from a more fundamental objection, according to which it is by definition impossible to predict crises – what can be referred to as a new "impossibility theorem". Moreover, another criticism of early warning systems is that they may contribute to the phenomenon they are supposed to fight (the self-fulfilling prophecies view). The objective of this paper is to challenge this skeptical view. To this aim, the paper discusses the general conditions under which the "impossibility theorem" may fail and self-fulfilling prophecies can be avoided, stemming e.g. from political economy arguments. The ability of a simple currency crisis model to provide useful information on economic vulnerabilities is illustrated by testing its out-of-sample performance in a panel of emerging market economies following the collapse of Lehman Brothers.

Key words: Exchange rates, currency crises, financial crises, early warning signals, political economy.
JEL: B40, C52, C53, D72, F31, G01.

Résumé

La crise financière de 2008 a suscité un regain d'intérêt pour la question des signaux avancés de crise. Elle a aussi déclenché un intérêt renouvelé pour la littérature sur les crises de change, puisque de nombreux pays, notamment parmi les marchés émergents, ont subi une pression très forte sur leurs changes. Alors que de nombreuses institutions publiques ont engagé un processus pour développer de nouveaux signaux avancés de crise, la capacité de prévoir des crises de change ou, plus généralement, n'importe quel type de crise financière, fait l'objet d'un certain scepticisme. Ce scepticisme provient du faible pouvoir prédictif de modèles prééminents, une fois testés hors échantillon, tel qu'il est reporté dans la littérature, mais aussi d'une objection plus fondamentale selon laquelle il serait impossible de prédire correctement les crises – un nouveau « théorème d'impossibilité ». Par ailleurs, une autre critique des signaux avancés de crise énonce que ceux-ci peuvent en fait contribuer au phénomène qu'ils sont censés combattre (en créant des prophéties auto-réalisatrices). L'objectif de ce papier est de contribuer à remettre en cause ce scepticisme. A cette fin, le papier discute les conditions sous lesquelles le « théorème d'impossibilité » ne tient pas et les prophéties auto-réalisatrices peuvent être évitées, en utilisant entre autres des arguments empruntés à l'économie politique. La capacité d'un modèle de crise de change très simple à fournir des informations utiles sur les vulnérabilités économiques est illustrée avec un échantillon de marchés émergents dans le sillage de la faillite de Lehman Brothers.

Mots clés: Taux de change, crises de change, crises financières, signaux avancés de crise, économie politique.
JEL: B40, C52, C53, D72, F31, G01.

1 Introduction

The ongoing financial crisis, which started in 2007 and intensified in September 2008, has rekindled interest in early warning signals of financial distress. Indeed, while it would be unrealistic to prevent any sort of output or asset price fluctuations, the social cost of the crisis appears so large that there is growing consensus on the necessity to anticipate such events and avoid their occurrence, looking forward. The financial crisis has also brought back on the policy agenda the issue of currency crises, with many emerging market economies experiencing severe exchange market pressures.

Against this background, several policy institutions are looking again into early warning signals of currency and financial crises and the relevant literature such as Frankel and Rose (1996), Kaminsky and Reinhart (1999), Demirguc-Kunt and Detragiache (1998), Bussière and Fratzscher (2006), Berg and Pattillo (1999b), or Bussière and Mulder (1999). While these papers rely on different methods and tackle different types of crises, what they have in common is that they all try to explain the occurrence of crises with a set of appropriately chosen variables (the "indicators", or "early warning signals"), taken at a given lag. Once estimated, the models can be used to predict future crises by updating the explanatory variables and computing the (forward looking) crisis index.[2]

However, just as policy institutions are again developing such early warning systems, the economic profession as a whole tends to show marked skepticism towards the efficiency of such models. In the case of currency crises, part of the skepticism comes from the result presented in Meese and Rogoff (1983), showing that it is difficult to beat a naïve exchange rate model (the random walk). As this result has proved very strong and difficult to overturn, with very few exceptions, the ability to predict currency crises –a particular form of exchange rate changes— seems very uncertain. In addition, the influential paper by Berg and Pattillo (1999a) has cast doubt on the out-of-sample performance of prominent currency crisis models. More recently, Rose and Spiegel (2009) have analyzed the causes and consequences of the 2008 crisis for a cross-section of 107 countries and found that their explanatory variables fail to account for the occurrence of crises in their sample, which, according to them, is a valid reason to be skeptical of early warning signals.[3] Part of the reason behind this result, however, may be that their crisis index is very composite and encompasses very different events (real GDP, the stock market, country credit ratings and the exchange rate). By contrast, the results presented in this paper suggest that focusing on specific events (in this case using an exchange market pressure index) yields very good results, perhaps because it is easier to trace the origin of crises when they are narrowly defined (a composite index likely has very heterogeneous explanations). Noticeably also, not all recent evidence yields disappointing results: Obstfeld, Shambaugh and Taylor (2009) could successfully explain exchange rate movements during the crisis using appropriately scaled reserve ratio's, while Della Corte, Sarno and Sestieri (2012) also find predictive power for dollar exchange rate changes based on the equilibrium model of international financial adjustment developed by Gourinchas and Rey (2007).

Beyond these issues, there seems to be a more fundamental problem with early warning signals, which can be summarized as follows: on the one hand, early warning signals are meant to predict crises with

[2] For a recent discussion see in particular European Central Bank (2012) and the references therein.

[3] To quote their main findings: "Despite the fact that we use a wide number of possible causes in a flexible statistical framework, we are unable to link most of the commonly-cited causes of the crisis to its incidence across countries. This negative finding in the cross-section makes us skeptical of the accuracy of "early warning" systems of potential crises, which must also predict their timing".

the aim to avoid their occurrence; on the other hand, if the signals are used for policy purposes, the predicted crises will be avoided, which means that model predictions will not be accurate any longer. There is therefore a contradiction between the goals of predicting and avoiding crises, which casts doubt on the usefulness of early warning signal (EWS) models for policy purposes: if we follow the argument, EWS cannot work effectively to forecast crises. This argument is somewhat reminiscent of the Lucas critique, but has not been explicitly spelled out in this context. The paper subsequently refers to this as an "impossibility theorem"[4]: crises *cannot* be correctly predicted and avoided at the same time, to the extent that predicting them will trigger a policy reaction that will prevent them.

Aside from this "impossibility theorem", another problem may arise, which is similar in essence because it touches upon rational expectations, but leads to the opposite conclusion: while the "impossibility theorem" implies that early warning signals cannot work, one may fear that they work too well and lead to self-fulfilling prophecies. Indeed, if EWS models were to signal a crisis in a given country (for instance, a currency crisis), and if this prediction is made public, market participants will likely react and sell the currency, which would precipitate the crisis. According to this second criticism, early warning systems would not be useless but dangerous, as they would lead to self-fulfilling prophecies and trigger crises. The danger of self-fulfilling prophecies has been acknowledged by policy makers, for instance in the context of the creation of the European Systemic Risk Board (*"The issues potentially addressed in the warnings and recommendations will be extremely sensitive and we must be careful about adverse effects, such as the warnings turning into self-fulfilling prophecies by frightening financial markets. The decision whether or not to publish will, therefore, require a case-by-case decision after a careful assessment of the potential consequence"*).[5]

The aim of this paper is to present and discuss these fundamental arguments against early warning systems. This paper can therefore be understood as a defense of early warning signals. It proceeds in two steps. First, the paper discusses the general arguments against the use of EWS models; second, the paper illustrates the ability of a simple currency crisis model (Bussière and Mulder, 1999) to perform well, out-of-sample, during the latest, and most severe general crisis episode since the great depression.

The general arguments in favor of EWS models (and why the "impossibility theorem" should not be invoked against them) are as follows. First, one assumption for the "impossibility theorem" to hold is that EWS are maintained and credible enough to trigger a policy reaction. Ironically, however, the credibility of EWS models tends to be low, and to diminish over time as the memory of previous crises fades away. The same argument also applies to the "self-fulfilling prophecies" concern, which assumes that market participants take action upon reception of the signal: this assumes that market participants follow such signals very closely and take them for granted, a rather strong assumption.[6] A second argument stems from the political economy of currency crises and from the costs associated with preventive measures: even if EWS models are taken seriously, nothing guarantees that policy makers will take action upon them, depending on their own incentives. For instance, political economy

[4] With apologies to Arrow (1950), who used the term in a different context.

[5] See on-line discussion: http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/09/405&format=HTML&aged=0&language=EN&guiLanguage=fr

[6] Another obvious condition for self-fulfilling prophecies is that the signals are made public; strict confidentiality can likely avoid such issues. The issue of the most appropriate way to communicate EWS results will be tackled in the conclusion.

factors seem to play an important role in the unfolding of currency crises, empirically (see Bussière and Mulder, 2000).

Aside from these general arguments, the case for EWS models can also be made by showing that the out-of-sample performance of existing models is not as bad as sometimes assumed. This is illustrated in the paper by means of a simple example, focusing on the out-of-sample predictions of a parsimonious currency crisis model (Bussière and Mulder, 1999): this model was already shown to work well in an out-of-sample exercise for the European Monetary System crises of the early 1990s (see Eichengreen, 2001); it is applied here, out-of-sample, to the depreciation episodes that took place at the end of 2008, in the wake of the financial crisis. The exercise is conducted for a group of emerging market and new EU economies, using the same model as originally published. Specifically, the model aims to relate a crisis index (which is calculated as a weighted average of the exchange rate depreciation and of the loss in reserves, between September and December 2008) to three key fundamentals: the current account balance, the degree of exchange rate over-valuation and the ratio of short-term debt to international reserves. The simplicity of the model makes it very tractable and lends itself very well to this exercise. Results indicate that the countries that recorded, prior to the crisis, high short-term debt compared to international reserves, a large current account deficit, or a sharp exchange rate appreciation, were those that experienced the strongest exchange market pressure. Having said that, there are also several outliers, corresponding to Type I as well as Type II errors (i.e., missed crises and false alarms). It can be argued, however, that even these cases are useful, because they inform us further on the causes of currency crises and structure the debate, which a mere judgmental analysis cannot achieve. To take a medical analogy, it can be argued that EWS models play an important role in establishing the "*differential diagnosis*" of crisis situations. The paper focuses on the examples of Malaysia (a "missed crisis" in the model, to the extent that the predicted value is far below the actual –observed- crisis index) and that of Turkey and Hungary (two cases of "false alarm", to the extent that the model was predicting a larger crisis than it actually took place). These results can also be interpreted as an indirect validation of the main argument put forth in Reinhart and Rogoff's 2009 book "This Time is Different": there are strong regularities attached to crises, which are therefore predictable based on a set of standard macroeconomic variables.

The rest of the paper is organized as follows. Section 2 reviews the literature and discusses some very general arguments in favor and against the use of early warning systems, including the "impossibility theorem". Section 3 presents results from the model outlined in Bussière and Mulder (1999), applied to the period from September to December 2008. Section 4 concludes and discusses the application of EWS models for policy purposes as well as the most appropriate way to communicate EWS results as part of the macroprudential surveillance framework.

2 The "impossibility theorem" and self-fulfilling prophecies: some general arguments in favour and against the use of early warning signals

2.1 A brief review of the literature

The literature on currency, banking, and financial crises is too vast to be reviewed here. The aim of this short section is not to be exhaustive, but rather to recall some of the most prominent papers on the subject, as well as the criticism expressed in Berg and Pattillo (1999a). There exists, to date, a broad variety of models that qualify as "early warning systems". These models are applied to detect currency crises (Sachs, Tornell and Velasco, 1996), banking crises (Demirguc-Kunt and Detragiache, 1998), "twin" (i.e., banking and currency/balance of payments) crises (Kaminsky and Reinhart, 1999), asset

price boom/bust cycles (Alessi and Detken, 2009), etc. The statistical methods vary considerably. Several papers use discrete choice models like the logit (Bussière, 2007) or probit (Frankel and Rose, 1996) models, while others use a continuous index (Sachs, Tornell and Velasco, 1996). Kaminsky and Reinhart (1999) use signals sent by individual indicators (depending on whether they cross a certain threshold). All these papers also use different explanatory variables (called in this context early warning indicators).

It appears that even prominent papers on the subject do not have a very good out-of-sample performance. Berg and Pattillo (1999a) evaluated the performance of three leading papers, by Frankel and Rose (1996), Sachs, Tornell and Velasco (1996) and Kaminsky, Lizondo, and Reinhart (1998). They used the models as originally published, updated the explanatory variables, and compared the outcome with the actual crisis index. The results are, in the words of the authors, "mixed", such that they reach the following conclusions: *"Plausible modifications to this model improve its performance, providing some hope that future models may do better. This exercise suggests, though, that while forecasting models may help indicate vulnerability to crisis, the predictive power of even the best of them may be limited."*

The criticism expressed by Berg and Pattillo (1999a) has had an influential impact on the profession and is often interpreted as an argument against the use of EWS. However, the finding that three prominent models fail to predict crises out-of-sample may just come from idiosyncrasies in these particular models and does not suggest that *all* EWS models are doomed to fail. In fact, the authors of the paper have contributed to the literature themselves and proposed their own methodology (Berg and Pattillo, 1999b). In addition, the results presented by Berg and Pattillo are not as strong against early warning signals as commonly perceived: after all, the Frankel and Rose model correctly predicts 90% of the observations, at a relatively low cost in terms of false alarms. More recently, Frankel and Saravelos (2010) argue that EWS models performed well out of sample during the financial crisis.[7]

Finally, one should also point out that the alternative (judgement based decisions) may not be better: at least, early warning systems provide a quantified assessment that can be compared with actual outcomes and evaluated using statistical criteria. Judgements, by contrast, are rarely (if any) evaluated so thoroughly. The comparison between judgement-based and model-based predictions is therefore biased against models, simply because they lend themselves more easily to statistical evaluations. In addition, purely judgment based decisions may reflect the personal bias of the analyst, including herding behaviour. By contrast, early warning exercises based on empirical models are much more objective, given that they purely rely on statistical inference.

Still, there are more fundamental objections against early warning models, which Section 2.2 now turns to.

2.2 The "impossibility theorem", self-fulfilling prophecies and other fundamental criticisms of early warning systems

While the issues raised by Berg and Pattillo (1999a) are model-specific, a more fundamental problem arises with the whole concept of early warning signals, namely the view that it is impossible to

[7] For recent work on the subject see in particular Babecký et al. (2012), Lo Duca and Peltonen (2012), Chitu (2012), Lane and Milesi-Ferretti (2010) and European Central Bank (2012), which provides a very complete review of the literature. On the specific issue of reserve adequacy indicators IEO (2012) presents a recent review and discussion.

correctly predict crises, because if a model reliably predicts crises, there will be a policy reaction that will prevent the crisis. This argument is somewhat reminiscent of the Lucas critique; it is also akin to the Goodhart Law, according to which an indicator ceases to be useful when it is used for policy purposes.[8] However, the argument has not been explicitly spelled out for the case of currency or financial crises. Specifically, the "theorem" can be supported as follows. To begin with, let us recall that the aim of early warning signals is to predict crises, with the aim to avoid them. Next, the reasoning goes, if the signals are used for policy purposes, the predicted crises will be avoided, which means that model predictions will not be accurate any longer. There is therefore a contradiction between the goals of predicting and avoiding crises, which casts doubt on the usefulness of EWS models for policy purposes. This is referred to here as an "impossibility theorem". One implication of this would be that EWS models should not be used, because *by definition* they cannot work. In practice, given that the coefficients of EWS models are estimated with statistical techniques using past data, a world where policy makers take results from EWS into account may change the coefficients significantly, such that it would not be clear how to estimate the model anymore. The paper will return to this argument but before, let us consider another fundamental criticism addressed to EWS models.

Another problem with EWS is, to some extent, the opposite of the "impossibility theorem", but also relates to rational expectations: according to the "impossibility theorem", early warning signals may not work because issuing a signal will prevent the crisis; by contrast, one may fear that they work too well and lead to self-fulfilling prophecies. Indeed, if a signal is issued in a given country (for instance, a currency crisis), agents may react and sell the currency, and this would actually precipitate the crisis. According to this second criticism, early warning systems would not be useless but dangerous, as they would lead to self-fulfilling prophecies and trigger crises. However, in contrast to the "impossibility theorem", the self-fulfilling prophecy view implies a very good fit for early warning signals.

2.3 Further discussion of the "impossibility theorem" and other fundamental concerns

The general arguments in favor of EWS models (and why the "impossibility theorem" may fail) are as follows. First, the key assumption behind the "impossibility theorem" is that early warning systems are maintained and credible enough to trigger a policy reaction. Paradoxically, however, the credibility of these models tends to be low, such that the lessons from EWS models are not always taken seriously. In fact, one should also realize that EWS models are relatively costly to maintain, at least those with a large number of countries and variables. In practice, the fact that few currency crises happened after those of Argentina and Turkey in the early 2000s has led many researchers and policy institutions to turn to other assignments, such that the signals sent out by EWS models –if any— were not very audible. Similar arguments also apply to the "self-fulfilling prophecies" concern, which assumes that market participants take action upon reception of the signal. This assumes that private sector analysts maintain such models and that the results of the models lead to investment decisions. Also related to the risk of "self-fulfilling prophecies", one assumption behind the argument is that the signals are made public; one obvious step to make is to ensure strict confidentiality to avoid such issues.

[8] "Any observed statistical regularity will tend to collapse once pressure is placed upon it for control purposes" (Goodhart, 1975). A related statement is that "a risk model breaks down when used for regulatory purposes". (Daníelsson, 2002).

A second argument against the "impossibility theorem" stems from the political economy of currency crises: even if EWS models are taken seriously, nothing guarantees that policy makers will take action upon them, depending on their own incentives and constraints. If, for instance, a given government does not have a clear majority in the Parliament, the reforms necessary to avoid the crisis may be delayed, or simply abandoned. In addition, taking preemptive action bears a financial, but also a political cost, and the policy maker needs to weigh the costs and benefits of implementing the necessary reforms (Bussière and Fratzscher, 2008). The financial cost of avoiding crises is clear. All measures aiming at averting a crisis are costly, such as borrowing reserves, reforming the financial sector, or raising interest rates, to name but a few. Yet, in addition, there are substantial political costs. The latter may arise from the stigma attached, for instance, to IMF programs[9]. The reputation of the policy maker may be endangered by undertaking a reform, such as the reform of the financial system, especially that the costs of the crisis itself are not visible until the crisis has happened. For that reason, to the extent that reforms typically have benefits in the long run but costs in the short run, the occurrence of elections tends to delay reforms. Empirically, these political economy factors seem to play an important role in the unfolding of currency crises (see Bussière and Mulder, 2000). In that paper, a standard EWS model very similar to the one presented here was augmented with political variables, which turned out to have a significant effect. The variables included the occurrence of elections and the stability of the government, proxied by various measures of political stability borrowed from the political science literature. In fact, this very much calls for the use of political variables in early warning signals, in complement to economic variables.[10]

However, the arguments outlined above do not completely reject the "impossibility theorem", understood as the impossibility to correctly predict and avoid crises at the same time: in case the signals issued by the model are not taken seriously or the measures to avoid crises fail, the model's predictions are correct but the predicted crises are not avoided. Of the two contrary objectives ("correctly predicting crises" and "avoiding crises"), only the first one is successfully achieved, the second one fails. To circumvent this, one needs to transform the model's prediction in a conditional statement: "if a particular course of action is not taken, a crisis will happen". Ideally, early warning systems should work as follows: as soon as the fundamental variables enter a "danger zone" (to be defined based on the preferences of the policy maker), preemptive action is taken such that no crisis happens. This way, the model would correctly predict the outcome ("no crisis").

2.4 In defense of early warning systems

In the previous sections various fundamental criticisms of EWS models have been discussed: the impossibility theorem and self-fulfilling prophecies. This section discusses additional benefits of EWS models, which are not related to the above.

One key benefit of EWS models is the disciplining effect that they bring into economic debates and in the policy making decision. Indeed, unlike judgement-based assessments, EWS models provide a quantifiable assessment of economic vulnerability, which is statistically linked to measurable fundamentals. There are clearly costs and benefits in using EWS. The costs associated with EWS

[9] For example, according to a senior economic adviser in the South Korean government (Shin Hyun-song) "If you are seen going to the IMF, then this is a very strong sign that your economy is going very badly wrong", July 24, 2010 (http://finance.yahoo.com/news/SKorea-IMF-work-on-emergency-apf-2187360675.html?x=0&.v=2).

[10] For an analysis of politico-economic crises see also Chang (2010).

relate to the fact that they constrain the researcher who operates them to regularly update a number of economic variables and to update the model. This represents an opportunity cost compared to other approaches (such as actively reading the press or talking to people in the field). However, it is not clear how relevant these other approaches really are. Reading the press may provide a lagging, rather than a leading, indication of the risks, and talking to market participants may be also lagging: if market participants believe that a crisis will happen, it is probably too late to avoid it. Of course, this does not mean that economists should not read the press or talk to market participants: the EWS approach can be completed by other approaches, the main point is that "exercising judgment" may prove insufficient.

In addition, it is not clear how to aggregate the information provided by different sources without a model, something that EWS do provide (in the form of a continuous indicator, as in Sachs, Tornell and Velasco, 1996, or in the form of the probability to have a crisis in a given time window). The fact that EWS models yield a quantifiable assessment lends itself to regular evaluation, and reduces the ability to manipulate the system to avoid politically unwelcome messages — conclusions that a country is vulnerable may not be welcomed by the governments of the effected countries, even when they are made behind closed doors.

Meanwhile, even "wrong" results (Type I and Type II errors) are informative. Indeed, missed crises should not imply that EWS are useless: rather, they imply that the factors behind them were not those included in the model. For example, the fact that models for which the government budget balance played a key role failed to predict the Asian crisis contributed to rule out the hypothesis that this crisis was a so-called "Generation I" crisis (as outlined in Krugman, 1979). This led researchers to investigate other channels and causes of the crisis, which in turn accelerated the policy response. As demonstrated in Section 3 of this paper, "wrong calls", i.e. missed crises and false alarms, are useful information. Missed crises suggest that other factors (than those included in the model) played a role in the crisis. False alarms suggest that unknown factors may play a beneficial role for a given country. In both cases, this should help analysts and policy makers make a better informed decision. To summarise, one could argue that EWS models play an important role in establishing the differential diagnosis of currency crises.

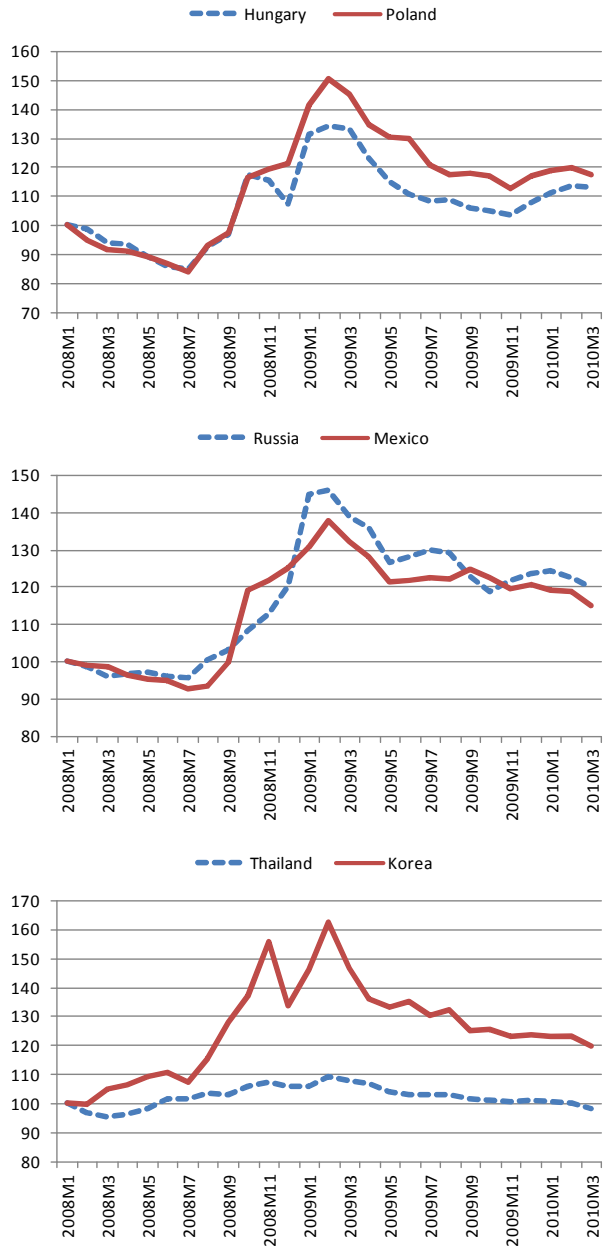
The discussion of the impossibility theorem suggests several implications: if the impossibility theorem holds and policy makers take actions based on the EWS model we will likely observe a significant decline in the number of crises, and if crises do occur they should not be explained by the EWS model. This would be accompanied by general improvements in the values of the variables used as indicators (e.g. increased reserve buffers). If, on the other hand, the EWS model becomes self-fulfilling, then we will observe a much better performance of the early warning signals, with possibly some shift in the levels that trigger crises (e.g. relatively lower reserve coverage ratios trigger a crisis). While checking these implications is beyond the scope of the paper, the accumulation of reserves as observed in the 2000s provides suggestive evidence that policy makers did draw lessons from the evidence provided by the models. In addition, the fact that even countries with sizeable levels of international reserves experienced exchange market pressure in late 2008, and sometimes even had to use swap lines with the Federal Reserve, also provides indirect evidence that some of the mechanisms behind the "impossibility theorem" are at play. However, a systematic investigation tends to show that, by and large, the standard variables used in EWS were good predictors of the patterns recorded in the wake of the 2008 crisis. This is what Section 3 now turns to.

3 Early Warning Signals in practice: lessons from a simple model of currency crises, applied to the 2008 financial crisis

This section sets out to use a model estimated some ten years ago and apply it, out-of-sample, to the crisis episodes that burst out in the wake of the 2008 financial crisis. The model presented here (Bussière and Mulder, 1999) lends itself very well to this exercise because of its simplicity and tractability.[11] The results will therefore be very easy to duplicate for whoever works in the field of international macroeconomics.

Figure 1: Bilateral Exchange Rates of Selected Economies with the US Dollar.

Indices: 2008M1 = 100; source IMF IFS ; an increase indicates a depreciation.



[11] The model and its results helped to underpin the IMF's general policy advice on the reserve cushions that countries need to maintain to reduce their external vulnerability (IMF, 2000, 2001). The results gained considerably in credence because the different approach used by Berg and Patillo (1999a) led in essence to the same core set of parsimonious variables.

The period following the collapse of Lehman Brothers offers a natural experiment for this exercise in view of the very sharp depreciations associated with the financial crisis; indeed, starting in the Fall of October 2008, the currencies of several emerging market and new EU economies depreciated by a very substantial amount (Thailand being a noticeable exception, Figure 1).

3.1 A simple model: Bussière and Mulder (1999)

The framework presented in Bussière and Mulder (1999) is very similar to that of Sachs, Tornell and Velasco (1996). One key specificity of this framework is that the aim is not to predict the timing of crises but rather to evaluate, at a given point in time, which countries are most vulnerable. For this reason, the econometric specification does not rely on panel estimation with both a time and country dimension (as, for instance, in Bussière, 2007) but rather on cross-sections. The dependent variable is a continuous index computed over a certain period of time during which exchange market pressure was intense, while the explanatory variables enter the specification with a lag. In the published paper, the model was estimated, first, during the crisis periods 1994M11-1995M4 and 1997M5-1997M10. It was then tested out-of-sample for the period 1998M7-1998M10. Finally, the model was estimated for all three periods together; this is the specification that is used in the present paper.

In the original paper several variables and specifications were tested, including the real effective exchange rate appreciation, the current account balance, the ratio of short-term debt to international reserves, the so-called "lending boom" variable (defined as the increase in the credits to the private sector), export growth, various liquidity ratios, and the presence or not of Fund programs. The aim was partly to test the model of Sachs, Tornell and Velasco (1996), and partly to look for alternative explanatory variables and specifications. In the present paper, by contrast, the aim is just to take an existing model and test it out-of-sample, without re-estimating the model (the point is to illustrate the out-of-sample performance of an existing model, not to look for in-sample goodness of fit, given the point made by Berg and Pattillo, 1999a). For this reason too, the focus is on the most simple specification of the paper, which is as follows:

$$\text{Crisis index} = \alpha_0 + \beta_1 \text{ RERINS} + \beta_2 \text{ STD/R} + \beta_3 \text{ CA/GDP} \qquad (1)$$

Where:

- The crisis index is a weighted average of the real effective exchange rate and of international reserves. The weights are equal to the precision of the series in the ten years preceding the start of the crisis window. The latter was taken during 1994M11-1995M4, 1997M5-1997M10, and 1998M7-1998M10 when the model was estimated. This time, the model is used for the period 2008M9-M12; the independent variables are therefore taken before June 2008 (in the case of quarterly data, such as the current account over GDP, the period considered is 2008Q2).
- RERINS is the *depreciation* of the real effective exchange rate in the 48 months preceding the start of the crisis window: the rationale is that a country that saw a sharp appreciation is likely to experience a large crisis index, hence a negative sign is expected.[12]

[12] Note that it may be more intuitive to measure the degree of *appreciation* and expect a *positive* sign; the choice is only a matter of convention and was made to compare results more directly with Sachs, Tornell and Velasco (1996).

- STD/R is the ratio of short-term debt to banks to international reserves, taken prior to the start of the crisis window (a positive sign is expected: the higher the level of short-term debt, or the lower the level of reserves, the higher the expected crisis index).
- CA/GDP is the current account *deficit*, measured as percentage of GDP, also taken prior to the start of the crisis window (a positive sign is expected: a larger deficit should be associated with higher exchange market pressures).

The estimation yielded the following coefficients (all were significant at conventional levels, see results in Bussière and Mulder, 1999, p. 32, Table 8, column (5); the adjusted R^2 was 0.48):

$$\text{Crisis index} = -20.78 - 0.38*\text{RERINS} + 0.28*\text{STD/R} + 1.67*\text{CA/GDP} \quad (2)$$

Can this simple model explain developments ten years after the model was estimated? This is what Section 3.2 turns to.

3.2 Out-of-sample predictions during the 2008 financial crisis

Table 1 reports the actual and predicted crisis indices for the 21 countries originally included in Bussière and Mulder (1999), except Jordan and Sri Lanka for which some of the data were missing. Before comparing the actual and predicted crisis indices, a few words on the crisis index *per se* are in order (Table 1).

Table 1: Actual and Fitted Crisis Indices

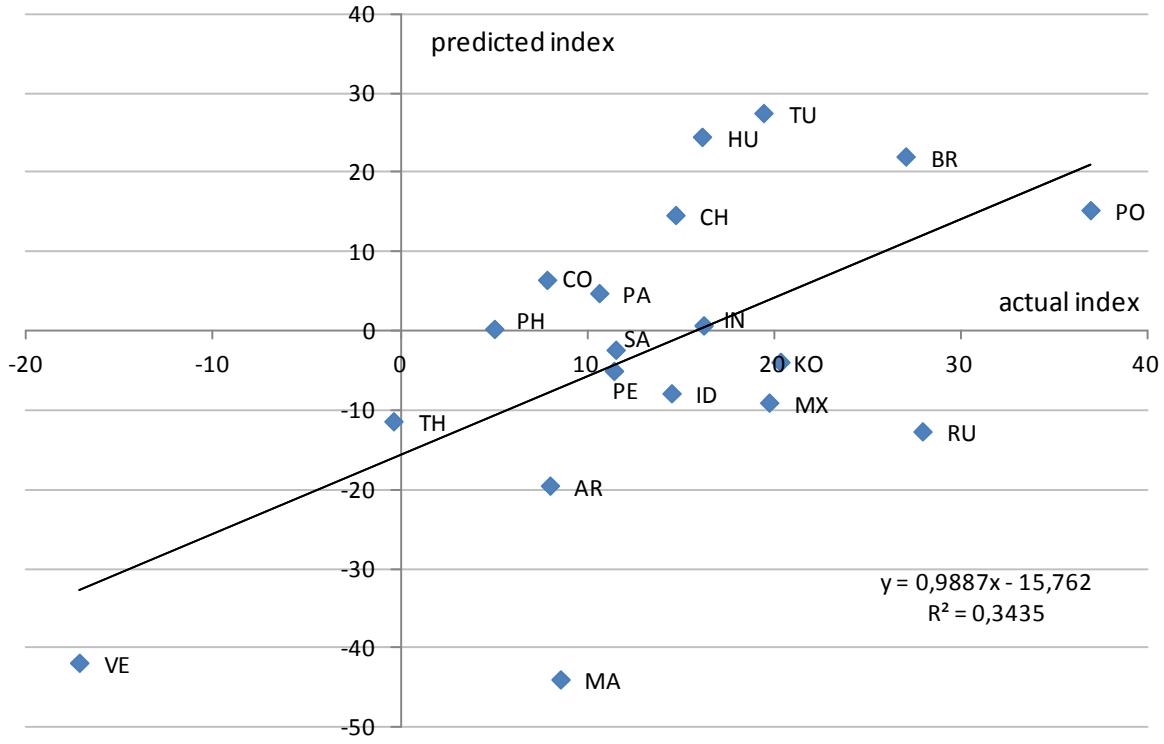
Country	Actual	Fitted	Rank (actual)	Rank (fitted)	Code
Argentina	8,1	-19,6	15	17	AR
Brazil	27,1	21,9	3	3	BR
Chile	14,8	14,5	9	5	CH
Colombia	7,9	6,4	16	6	CO
Hungary	16,2	24,4	8	2	HU
India	14,6	-7,9	10	13	ID
Indonesia	16,3	0,6	7	8	IN
Korea	20,4	-4,0	4	11	KO
Malaysia	8,6	-44,0	14	19	MA
Mexico	19,8	-9,1	5	14	MX
Pakistan	10,7	4,7	13	7	PA
Peru	11,5	-5,1	12	12	PE
Philippines	5,1	0,2	17	9	PH
Poland	37,0	15,2	1	4	PO
Russia	28,0	-12,7	2	16	RU
South Africa	11,6	-2,4	11	10	SA
Thailand	-0,3	-11,5	18	15	TH
Turkey	19,5	27,4	6	1	TU
Venezuela	-17,2	-41,9	19	18	VE

A quick glance at the top 10 countries reveals the strong heterogeneity among the countries most severely affected by the 2008 financial crisis, which belong to very different regions, such as Eastern

Europe (Poland, Russia, Hungary), East Asia (Korea, Indonesia), Latin America (Brazil, Mexico, Chile), as well as India and Turkey. Unlike the 1994 Tequila crisis, which affected predominantly Latin America, and the 1997 Asian crisis, which affected predominantly East Asia, the 2008 crisis did not have such strong regional component.

The comparison between the actual and fitted (predicted) indices shows that the correlation between the two is about 0.6, which is somewhat encouraging given some outliers. A simple regression of the predicted on the actual crisis index using ordinary least squares returns a positive coefficient very close to 1 (at 0.99), which is significant at the 1% level (Figure 2), with an R^2 of 34%. Importantly also, the ranking of the countries is similar, as revealed by looking at the Spearman rank order correlation (at 0.42, significant at the 10% level).

Figure 2: Correlation Between Actual and Predicted Indices.
Regression using ordinary least squares. Country codes are explained in Table 1.



Authors' calculations.

Overall, therefore, it is very encouraging that such simple model, which includes only three standard variables in a linear specification, can correctly predict the ranking of the countries most subject to exchange market pressure, ten years after the publication of the original paper.

Having said that, there are also significant outliers. On the positive side (meaning, among the countries for which the model over-predicts the crisis index, i.e. "false alarms"), there is Hungary and Turkey. The fact that the model predicted such large crisis index for Hungary stems from two variables: first, Hungary registered a large current account deficit, nearly 5.4% of GDP in the first half of 2008, and second, the short-term debt to reserve ratio was above 1, at 102%. Both variables contributed to a large predicted crisis index (24.4), larger than the observed index (16.2). Similarly, Turkey recorded a larger

crisis index (27.4%) than observed (19.5%), mostly due to a large current account deficit (8.2%) and substantial short-term debt compared to international reserves (with a ratio close to one, at 89%).

On the negative side (meaning, among the countries for which the model under-predicts the crisis index, i.e. "missed crises"), there is Malaysia. For Malaysia, like for Hungary, the current account balance is the variable that contributes most to the assessment. However, it plays in the opposite direction, given that Malaysia had a very large surplus before the crisis (over 20% of GDP). In addition, the ratio of short-term debt to reserves was low for Malaysia, about 25%. This explains why, while the actual crisis index was not very high (at 10), the model under-predicted its magnitude and returned a large negative number. This suggests that other factors, not accounted for in this simple model, were at play to explain the crisis index in Malaysia (perhaps related to contagion from other countries).

Interestingly, the coefficient of the regression is close to 1, but the intercept is negative. This suggests that on average, the model under-predicts the magnitude of the crisis indices, even though it does predict the ranking correctly. In other words, there must have been some factors that contributed to the crisis *globally* and that were not accounted for in the model. A possible explanation is that this crisis was the first global crisis and that contagion (not accounted for in this model) played a key role. Whereas many observers anticipated a depreciation of the US dollar, the dollar appreciated during the crisis, due to higher risk aversion globally (US residents repatriated their foreign investments, while foreign investors also sought low risk investments such as T-bills).

One final remark on these outcomes is that running a regression line between actual and fitted crisis indices, as done above (and as common in the literature), or looking at correlation coefficients, implicitly assumes that Type I and type II errors are weighted equally. A risk averse economist may prefer to over-predict the crisis index (as the model did for Hungary and Turkey) than to under-predict it (as the model did for Malaysia), which ordinary least squares do not take into account (this point is discussed in Bussière and Fratzscher, 2008).

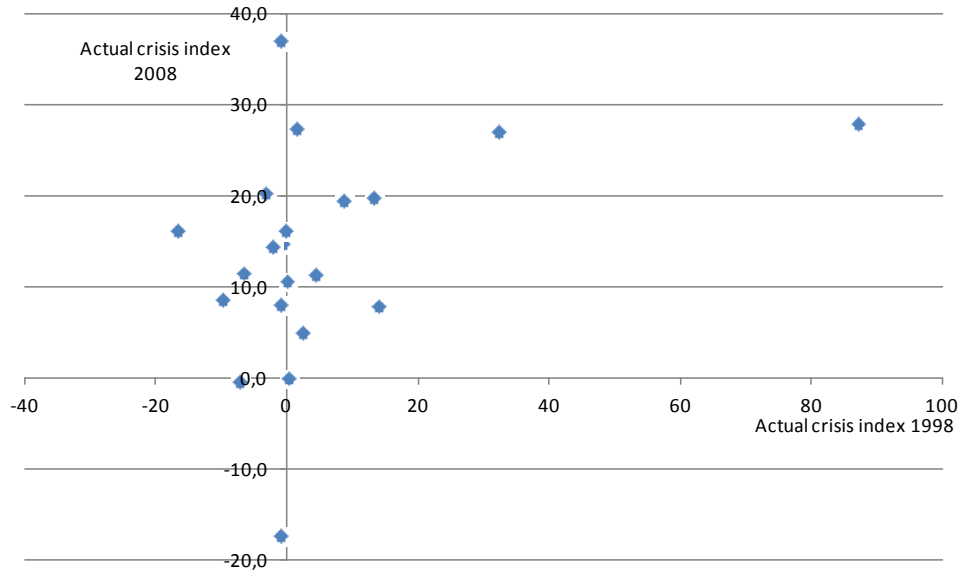
3.3 Further Extensions

The above exercise can be extended in a variety of directions. First, one may wonder whether the 2008 crises actually reflect past crises, such as those that affected emerging markets and new EU economies in the 1990s. Is it the same countries that are always hit by currency crises? To investigate this, one can run simple regressions of the crisis indices for 2008 against those of the years 1994, 1997 and 1998. As Figures 3 demonstrates, the indices are not correlated.

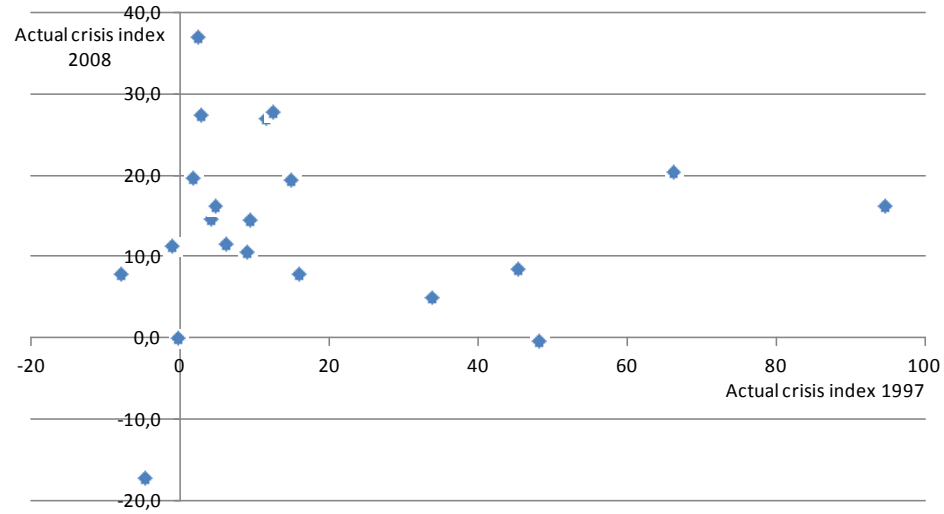
This simple regression of course omits one key element, namely the fact that fundamentals were not equal then and now. To control for this, one can run regressions of the *residuals* of the 2008 crisis indices on the *residuals* of the past crisis episodes. These residuals capture the part of the crisis indices that is orthogonal to fundamentals (the idiosyncratic components). Again, it turns out that such regressions do not yield significant coefficients, which suggests that idiosyncratic (non-measurable) components do not play a first order role in the unfolding of crises.

Figure 3: Comparison of the Crisis Indices, 2008 Crisis with Previous Crises

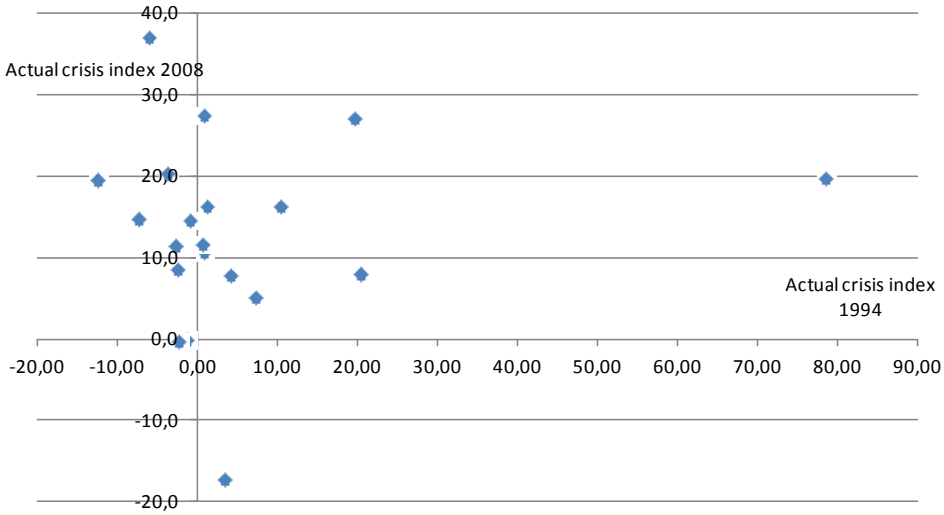
Panel A: Comparison with 1998 crisis



Panel B: Comparison with 1997 crisis



Panel C: Comparison with 1994 crisis



4 Conclusion

The aim of this paper was to discuss the benefits of early warning signals and illustrate their merits by considering the out-of-sample performance of a very simple EWS model of currency crises, using a panel of emerging market and new EU member states. The paper discussed in particular the view that early warning signals cannot work by definition, due to what is called here an "impossibility theorem". According to this view, EWS models *cannot* perform due to a fundamental flaw: if such model could effectively predict crises, policy makers would use them to avoid crises, which would remove the explanatory power of the model. In other words, if we follow this argument, the endeavour to predict and avoid crises is doomed from the start. Another fundamental criticism addressed in this paper is that EWS models are actually dangerous, because they may lead to self-fulfilling prophecies: if market participants were to receive signals that a crisis is looming in a given country, their reaction would immediately trigger a crisis, independently of the inherent quality of the signal.

The paper has, first, argued against this view by considering very general arguments. In particular, the political economy of financial crises may lead policy makers to postpone the reforms that would avoid crises. In addition, the "impossibility theorem" and the "fulfilling prophecies" arguments assume that EWS models are regularly maintained and taken seriously, which is currently far from being the case. One implication of the risk to see self-fulfilling prophecies is the need to communicate EWS results appropriately. This is not an easy task. On the one hand, if EWS results are never communicated (i.e. kept confidential), this may avoid self-fulfilling prophecies altogether. Yet, there is always a risk that the results leak out, or even more simply than another analyst replicates the model and communicates the results. A better strategy is perhaps therefore to communicate the results frequently, which would imply smoother transitions. Frequently communicating EWS results would ensure that self-corrections happen as soon as fundamentals deteriorate. Ideally, therefore, the impossibility theorem would be avoided without triggering self-fulfilling prophecies: in this "perfect" world, fundamentals would always be in the green zone, and EWS would correctly predict no crisis.

The paper has also checked whether a simple model designed to explain currency crises, published more than ten years ago (Bussière and Mulder, 1999), was able to predict the exchange market pressure that impacted emerging market and new EU economies at the end of 2008. The results were very encouraging; clearly, however, the model also made "Type I" and "Type II" mistakes: it under-predicted the crisis index of some countries (noticeably, Malaysia) and over-predicted that of others (noticeably, Hungary and Turkey). It can however be argued that even these errors are useful, because they point to other factors than those included in the model and contribute to a deeper understanding of the crisis. The main objective of this section –and of the paper- was not to pretend that a simple model can predict crises perfectly, but rather to show that even a parsimonious specification can do a relatively good job at explaining economic vulnerabilities, out of sample. It was also to show how a simple EWS model can be used in practice for policy purposes.

References

Alessi, L. and C. Detken (2009), "'Real Time' Early Warning Indicators for Costly Asset Price Boom/Bust Cycles: a Role for Global Liquidity", ECB Working Paper No. 1039, March 2009, *European Journal of Political Economy*, Vol. 27, No 3, pp. 520-533, 2011.

Arrow, K.J. (1950), "A Difficulty in the Concept of Social Welfare", *Journal of Political Economy*, 58(4) (August, 1950), pp. 328–346.

Babecký, J., T. Havránek, J. Matějů, M. Rusnák, K. Šmídková and B. Vašíček (2012), "Early Warning Indicators of Economic Crises: Evidence from a Panel of 40 Developed Countries", Czech National Bank Working Paper, No 8, 2011 and Working Paper Series, No 1485 and No 1486, ECB.

Berg, A. and C. Pattillo (1999a), "Are Currency Crises Predictable? A Test", *IMF Staff Papers*; 46(2), June 1999, pp. 107-38.

Berg, A. and C. Pattillo (1999b), "Predicting Currency Crises: The Indicators Approach and an Alternative", *Journal of International Money and Finance*; 18(4), August 1999, pp. 561-86.

Bussière, M. (2007), "Balance of Payment Crises in Emerging Markets - How Early were the "Early" Warning Signals?", ECB Working Paper No. 713, January 2007, forthcoming *Applied Economics*, 2013.

Bussière, M. and M. Fratzscher (2006), "Towards a New Early Warning System of Financial Crises", *Journal of International Money and Finance*, 25(6), October 2006, pp. 953-973.

Bussière, M. and M. Fratzscher (2008), "Low Probability, High Impact: Policy Making and Extreme Events", *Journal of Policy Modeling*, 30(1), pp. 111-121.

Bussière, M. and C. Mulder (1999), "External Vulnerability in Emerging Market Economies - How High Liquidity Can Offset Weak Fundamentals and the Effects of Contagion," IMF Working Papers 99/88, International Monetary Fund.

Bussière, M. and C. Mulder (2000), "Political Instability and Economic Vulnerability", *International Journal of Finance and Economics*, October 2000, 5(4), pp. 309-330.

Chang, R. (2010), "Elections, Capital Flows, and Politico-economic Equilibria," *American Economic Review*, 100(4): 1759-77.

Chitu, Livia (2012), "Was unofficial dollarisation/euroisation an amplifier of the 'Great Recession' of 2007-09 in emerging economies", Working Paper Series 1473, European Central Bank.

Daníelsson, J. (2002), "The Emperor Has No Clothes: Limits to Risk Modelling", *Journal of Banking and Finance*, 2002, 26, pp. 1273-96.

Demirguc-Kunt, A., and E. Detragiache (1998), "The Determinants of Banking Crises in Developing and Developed Countries", *IMF Staff Papers*, Volume 45, Number 1, March 1998.

Della Corte, P., L. Sarno and G. Sestieri (2012), "The Predictive Information Content of External Imbalances for Exchange Rate Returns: How Much Is It Worth?," *The Review of Economics and Statistics*, MIT Press, vol. 94(1), pages 100-115, February.

Eichengreen, B. (2001), "The EMS Crisis in Retrospect", CEPR Discussion Papers 2704, C.E.P.R. Discussion Papers.

European Central Bank (2012), *Report on the First Two Years of the Macro-prudential Research Network*, October 2012.

Frankel, J. and A. Rose (1996), "Currency Crashes in emerging Markets: an Empirical Treatment", *Journal of International Economics*, 41, pp. 351-66.

Frankel, J. and G. Saravelos (2010), "Are Leading Indicators Useful for Assessing Country Vulnerability? Evidence from the 2008-09 Global Financial Crisis", *NBER WP no.16047, June*.

Goodhart, C. A. E. (1975), "Monetary Relationships: A View from Threadneedle Street", Papers in Monetary Economics (Reserve Bank of Australia).

Gourinchas, P. O., and H. Rey (2007), "International Financial Adjustment," *Journal of Political Economy*, 115:4 (2007), 665–703.

IMF (2000) Debt- and Reserve-Related Indicators of External Vulnerability, IMF Board paper, March 23, 2000 at http://www.imf.org/external/np/pdr/debtres/index.htm.

IMF (2001), "Issues in Reserves Adequacy and Management," IMF Board paper, October 15, 2001, http://www.imf.org/external/np/pdr/resad/2001/reserve.htm.

IEO (2012), "International Reserves: IMF Concerns and Country Perspectives", in 'IEO report' (International Monetary Fund).

Kaminsky, G. L. and C. M. Reinhart (1999), "The Twin Crises: The Causes of Banking and Balance-of-Payments Problems", *American Economic Review*; 89(3), June 1999, pp. 473-500.

Kaminsky G. L., S. Lizondo and C. M. Reinhart (1998), "Leading Indicators of Currency Crises," *IMF Staff Papers*, 45, No. 1, pp. 1-48.

Krugman, P., (1979), "A Model of Balance-of-Payments crises", *Journal of Money, Credit and Banking*, Vol. 11 (August), pp. 311-25.

Lane, P.R. and G.M. Milesi-Ferretti (2010), "The cross-country incidence of the global crisis", CEPR Discussion Paper, No. 7954.

Lo Duca, M. and T.A. Peltonen (2012), "Macro-financial Vulnerabilities and Future Financial Stress: Assessing Systemic Risks and Predicting Systemic Events", Working Paper Series, No 1311, ECB, and forthcoming in *Journal of Banking and Finance*, 2012.

Meese, R., and K. Rogoff, (1983), "Empirical Exchange Rate Models of the Seventies", *Journal of International Economics*, 1983, 14 pp. 3-24.

Obstfeld, M., J. C. Shambaugh and A. M. Taylor, (2009), "Financial Instability, Reserves, and Central Bank Swap Lines in the Panic of 2008", *American Economic Review*, vol. 99(2), pages 480-86, May.

Reinhart, C. M. and K. M. Rogoff (2009), "This Time is Different – Eight Centuries of Financial Folly", Princeton University Press.

Rose, A. K. and M. Spiegel (2009), "Cross-Country Causes and Consequences of the 2008 Crisis: Early Warning", CEPR Discussion Paper No. 7354, July 2009.

Sachs, J., A. Tornell and A. Velasco (1996), "The Mexican Peso Crisis: Sudden Death Or Death Foretold ?", *Journal of International Economics*, 41 (1996), pp. 265-283.

Data Appendix

The data sources are the same are in Bussière and Mulder (1999). The interested reader can therefore refer to this paper for detailed information on the variables. In a nutshell, the data sources are as follows:

1. Crisis index.

The crisis index is a weighted average of the depreciation of the exchange rate and the loss in reserves, weighted by the precision (the inverse of the variance) of these two variables measured over ten years. The exchange rate is taken from IFS line rf, the nominal bilateral exchange rate against the dollar (period average). Reserves are taken from IFS line 1L.d, reserves minus gold.

2. Current Account.

The current account variable is expressed as a percentage of GDP and refers to the ten year period ending before the crisis. Quarterly data from IFS line 78ald were used. Some of the quarterly data on GDP were interpolated based on annual data (IFS line 99b).

3. Exchange Rate Depreciation.

The exchange rate is the real effective exchange rate, measured over the ten years preceding the crisis.

4. Short-term debt to reserve ratio.

The computation of this ratio uses the same reserve variable as in point 1 above. For short-term debt the consolidated short-term debt data published semi-annually by the Bank of International Settlements was used. These data refer to the international positions of reporting banks on countries outside the reporting area and are defined on a remaining maturity basis.

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